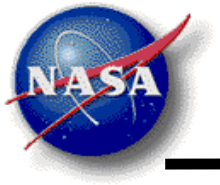


Distributed Crew Interaction with Advanced Life Support Control

August 2003

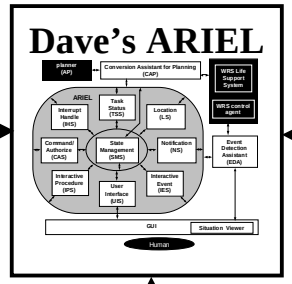
NASA Johnson Space Center

Debra Schreckenghost
Pete Bonasso
Tod Milam

Cheryl Martin
David Kortenkamp
Carroll Thronesbery

Human-Agent Community in Advanced Water Lab

Control events, commands



Control events, commands

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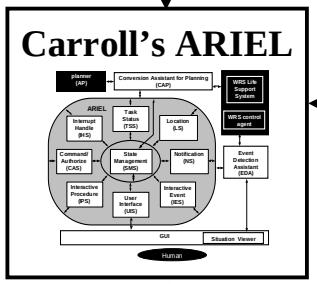
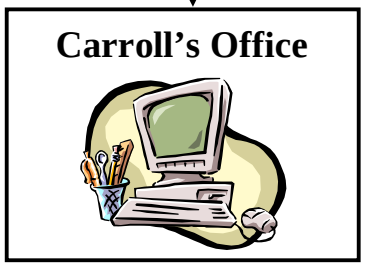
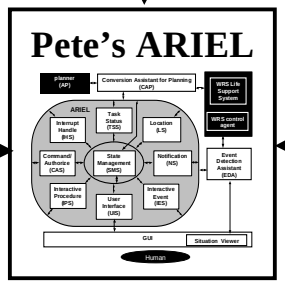


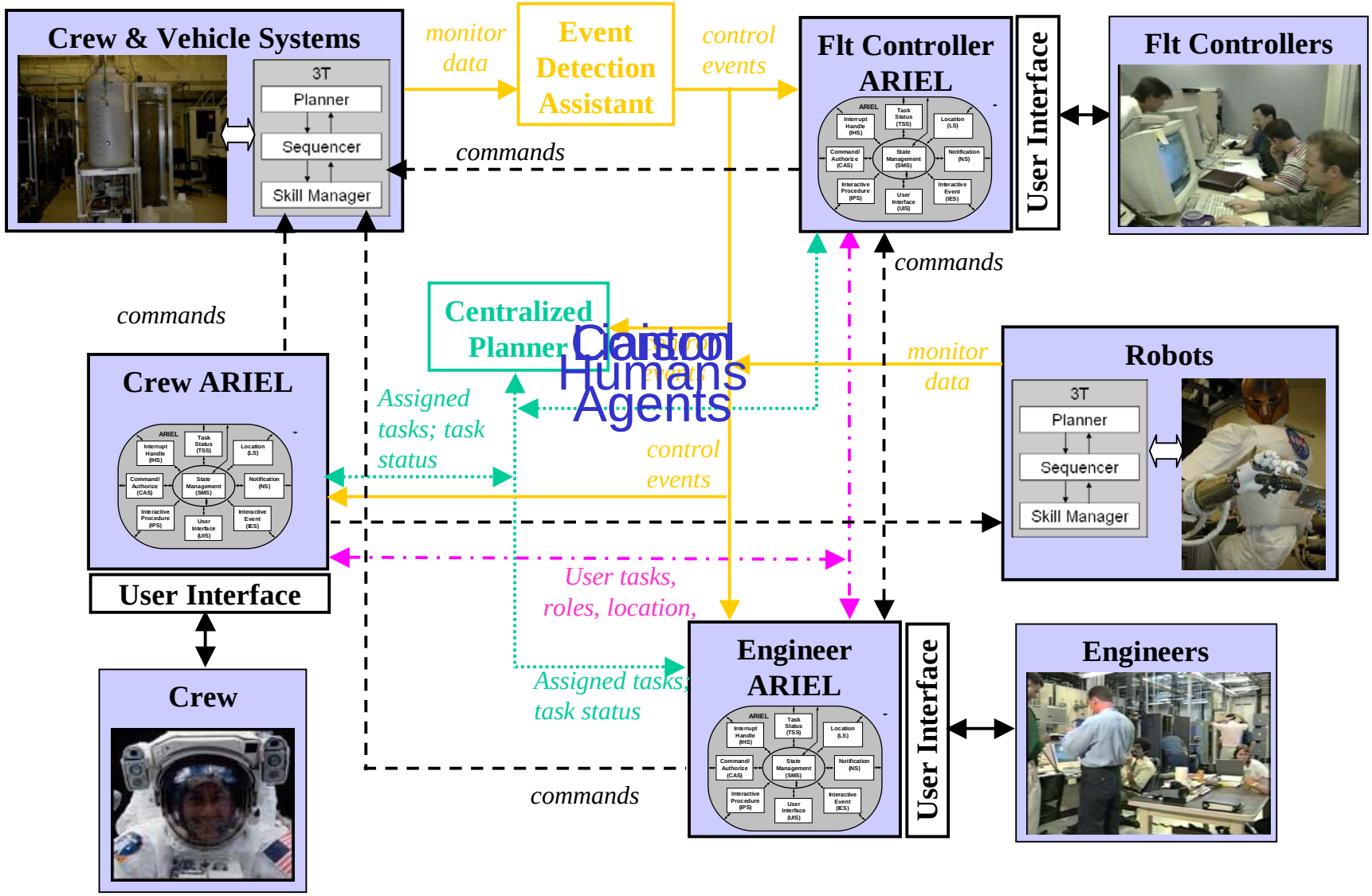
User activities, location, role

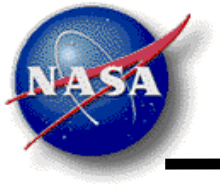




Communication
- o Proxy-Control
- o Proxy-Proxy

Human-Agent Community for Manned Space OPS





Models of Human-Agent Interaction

- Interaction between
  - Human and control agent via liaison agent
    - Situation Awareness and Command Authorization
  - Human and his or her liaison agent
    - Reconfigurable Agents
    - Improved Notification and Plan Management
  - Human and organization via liaison agent
    - Managing Organizational States and Policies
  - Humans in a group
    - Group Communication
    - Group Awareness
- Remote interaction with agents
  - Portable and wireless computing

Models of Human-Agent Interaction

- Interaction between human and control agent via liaison agent
  - **Command and Authorization**: Human interacts with hardware while autonomous control active (i.e., requires authorization and reconfiguration)
  - **Situation Summarization**: Control agent informs human of important events, including anomalies; reveal complex event structure in operational situations
  - *Proposed Research to Intelligent Systems Program*
    - *DCI: Automated sequence execution and tracking of procedures (PI: D. Schreckenghost)*
    - *Dynamic allocation of task responsibility (PI: P. Scerri; K. Sycara/CMU)*
    - *Agent Communication Language (ACL) for human interaction with autonomous control agents (PI: C. Martin)*
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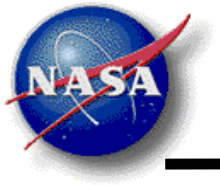
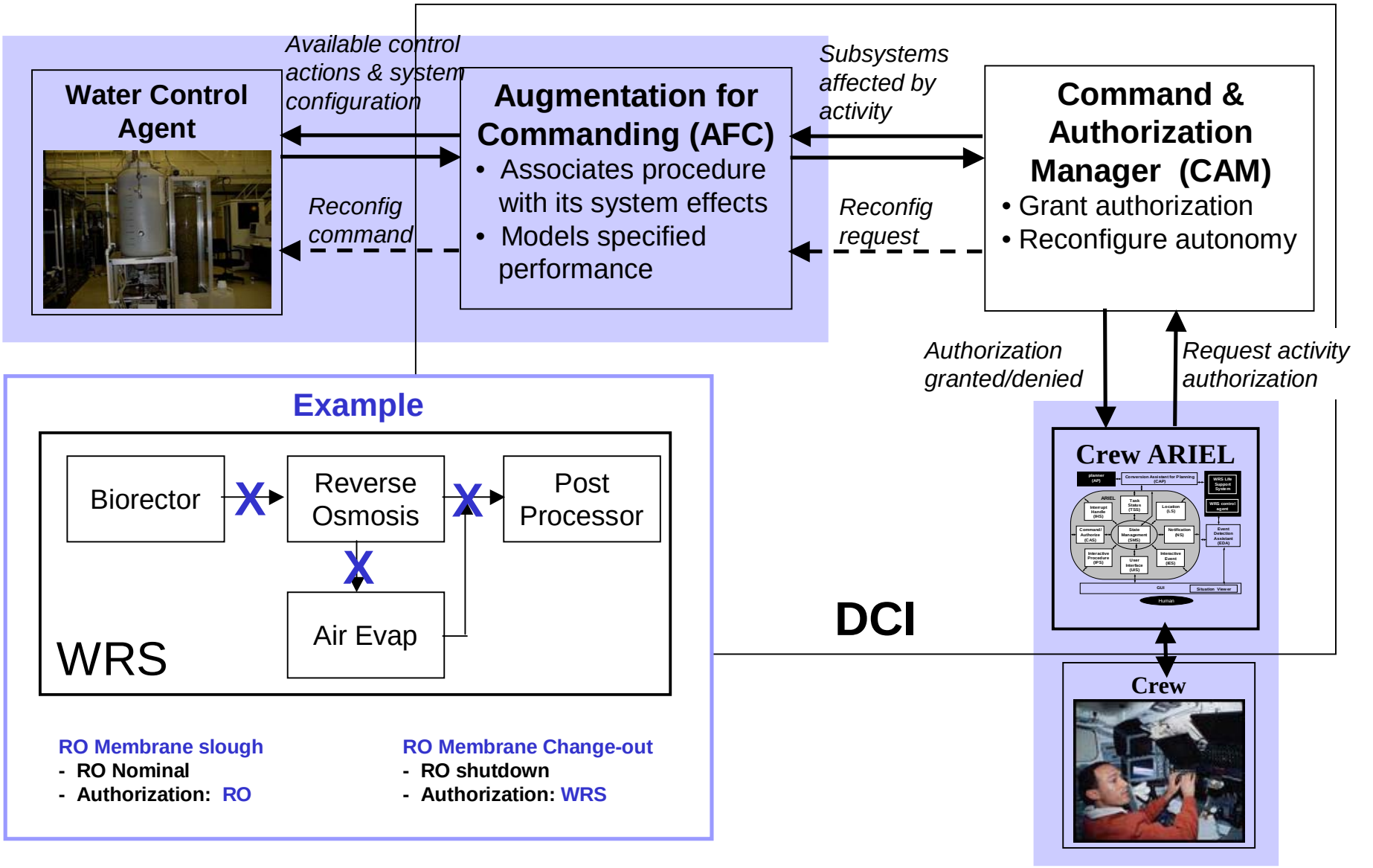
    - *Human-agent team design to reduce risk (PI: J. Eilbert/CHI Systems)*



Command and Authorization Service

- Assist humans in distributed, concurrent commanding of systems normally managed by automated control agents
  - Grant authorization if requested procedure does not conflict with other ongoing activities
    - Constrain authorized actions based on the scope of their effects on a system and its constituent subsystems
    - Consider system operating configuration when determining scope of the effect (e.g., loss of capability can change scope of effect)
    - Reconfigure automated control agent to ensure compliance with authorization granted
  - Notify user requesting authorization
    - When conflicts prevent authorization and when they no longer exists
    - Potential conflicts if choose to override authorization
  - Release authorization once manual commanding is complete
    - Return automated control agent to nominal configuration
    - Notify users waiting for authorization due to potential conflicts
  - Key Technologies
    - Models of tasks, models of system connectivity and configuration
    - Policies for control authorization

Command and Authorization Service



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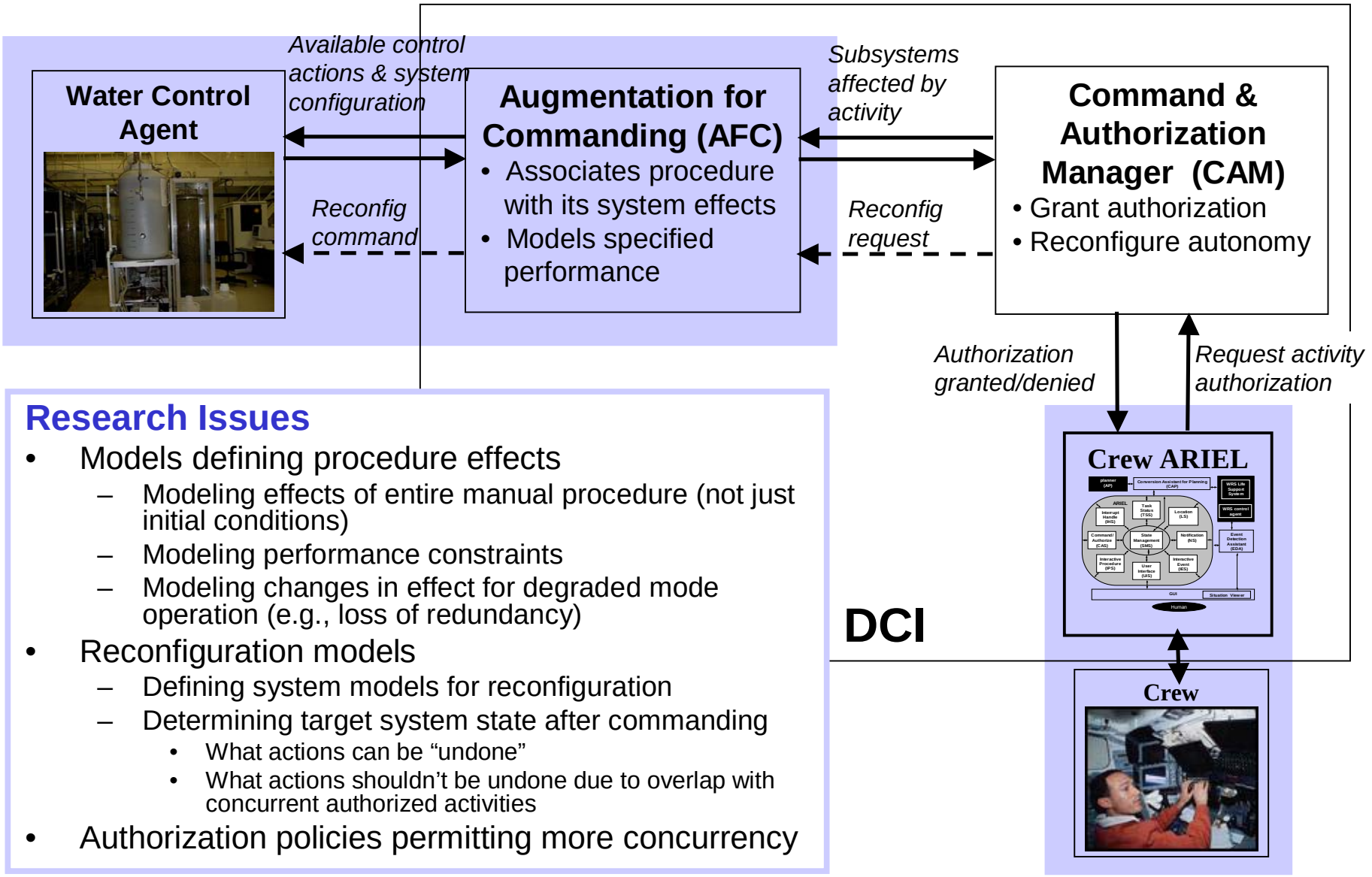

Research Issues

- Models defining procedure effects
  - Modeling effects of entire manual procedure (not just initial conditions)
  - Modeling performance constraints
  - Modeling changes in effect for degraded mode operation (e.g., loss of redundancy)
- Reconfiguration models
  - Defining system models for reconfiguration
  - Determining target system state after commanding
    - What actions can be “undone”
    - What actions shouldn’t be undone due to overlap with concurrent authorized activities
- Authorization policies permitting more concurrency

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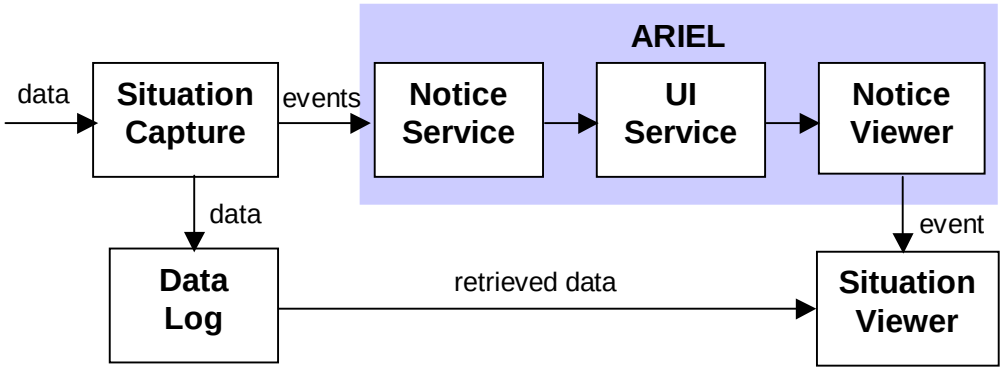
Situation Summarization

- Situation capture using NASA Phase II SBIR software for Complex Event Recognition (J. Firby, INet)
  - Key Technology: applies language recognition principles to detect event patterns with complex temporal & hierarchical relationships among them
  - Revised recognizers based on evaluation with multiple data sets
  - Separated parameter logging from capturing situation
    - Capture event sequences in CERA
    - Retrieve associated data parameters when needed in Viewer



  - Writing recognizers for new WRS events (e.g., bioreactor sloughs)
- Revised Situation Viewer used by ARIEL agent

Previous Versions of Situation View

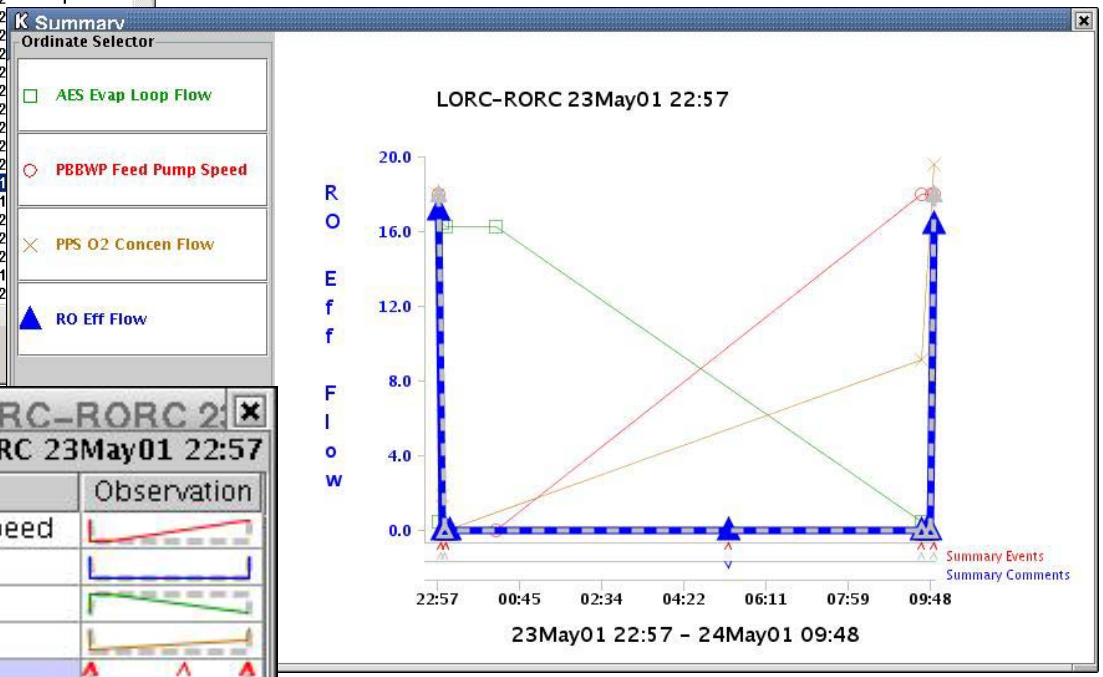
Remote Access to Logs

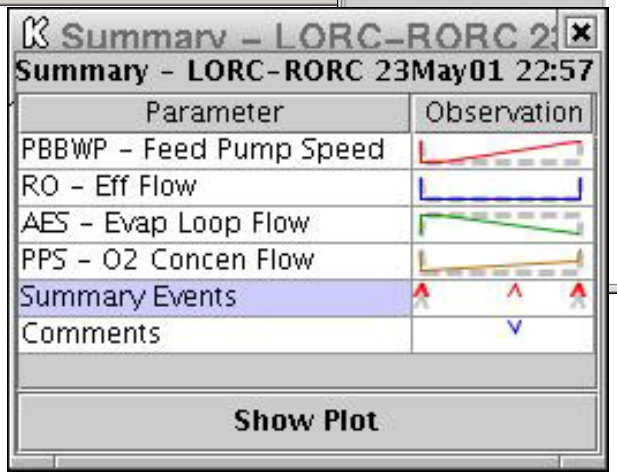
Viewing f:/dci/lorc/orig_data/aesskm_01_05_23.log

File Viewing Options Help Log: f:/dci/lorc/orig_data/aesskm_01_05_23.log

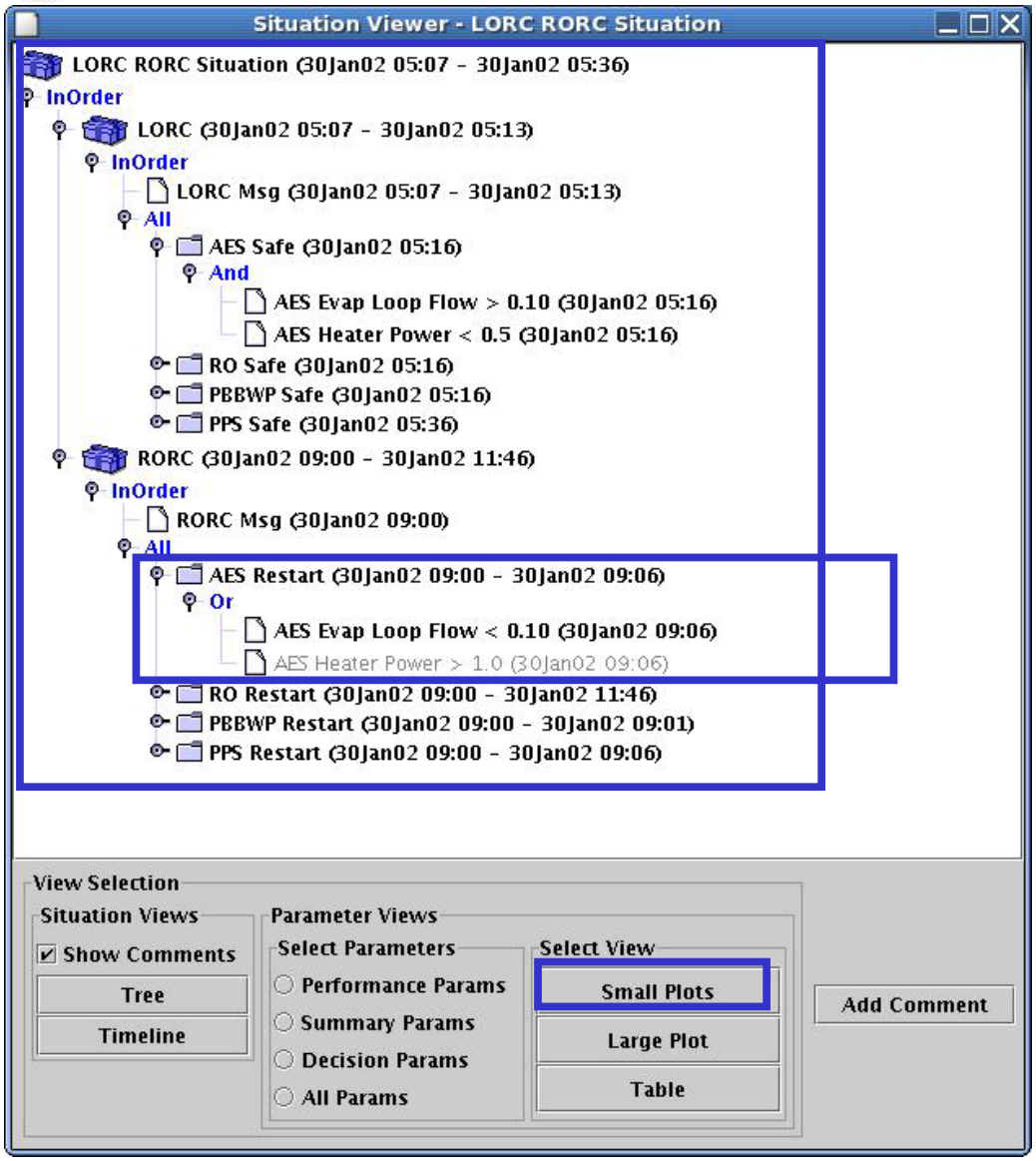
date	time	dp01	dp02	dw01	fm07	fm08	ls01	ls02	ls03	ls04	p08_i1	p0
05/23/01	21:34:59	0	0	75	0.027	-0.02	0	0	0	32	1	
05/23/01	21:39:52	0	0	73	0.027	-0.02	0	0	0	32	1	
05/23/01	21:44:59	0	0	76	0.027	-0.02	0	0	0	32	1	
05/23/01	21:50:05	0	0	79	0.027	-0.02	0	0	0	32	1	
05/23/01	21:54:52	0	0	79	0.027	-0.02	0	0	0	32	1	
05/23/01	21:59:58	0	0	79	0.027	-0.02	0	0	0	32	1	
05/23/01	22:04:51	0	0	77	0.027	-0.02	0	0	0	32	1	
05/23/01	22:09:52	0	0	82	0.027	-0.02	0	0	0	32	1	
05/23/01	22:14:58	0	0	82	0.027	-0.02	0	0	0	32	1	
05/23/01	22:19:51	0	0	83	0.027	-0.02	0	0	0	32		
05/23/01	22:24:58	0	0	84	0.027	-0.02	0	0	0	32		
05/23/01	22:30:05	0	0	81	0.027	-0.02	0	0	0	32		
05/23/01	22:34:56	0	0	85	0.027	-0.02	0	0	0	32		
05/23/01	22:40:03	0	0	80	0.027	-0.02	0	0	0	32		
05/23/01	22:44:49	0	0	86	0.027	-0.02	0	0	0	32		
05/23/01	22:49:56	0	0	86	0.027	-0.02	0	0	0	32		
05/23/01	22:54:48	0	0	84	0.014	-0.02	0	0	0	32		
05/23/01	22:59:51	0	0	85	0.027	-0.02	0	0	0	32		
05/23/01	23:04:46	0	0	95	0.986	-0.02	0	0	0	31		
05/23/01	23:09:52	0	0	97	0.986	-0.02	0	0	0	31		
05/23/01	23:14:57	0	0	97	0.974	-0.02	0	0	0	32		
05/23/01	23:20:03	0	0	93	0.986	-0.02	0	0	0	32		
05/23/01	23:24:49	0	0	98	0.974	-0.02	0	0	0	32		
05/23/01	23:29:54	0	0	97	0.974	-0.02	0	0	0	31		
05/23/01	23:34:47	0	0	98	0.974	-0.02	0	0	0	32		

System Summaries & Plots

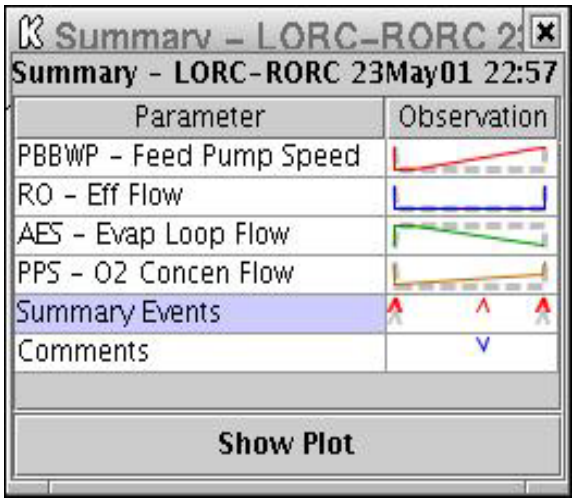


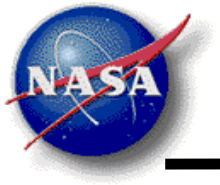


Viewing Complex Situations



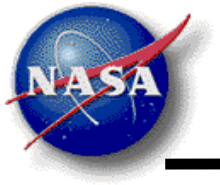
- Reveal event structure with generic viewer
- Show observed events in context of possible events
- Link to system/subsystem view





Models of Human-Agent Interaction

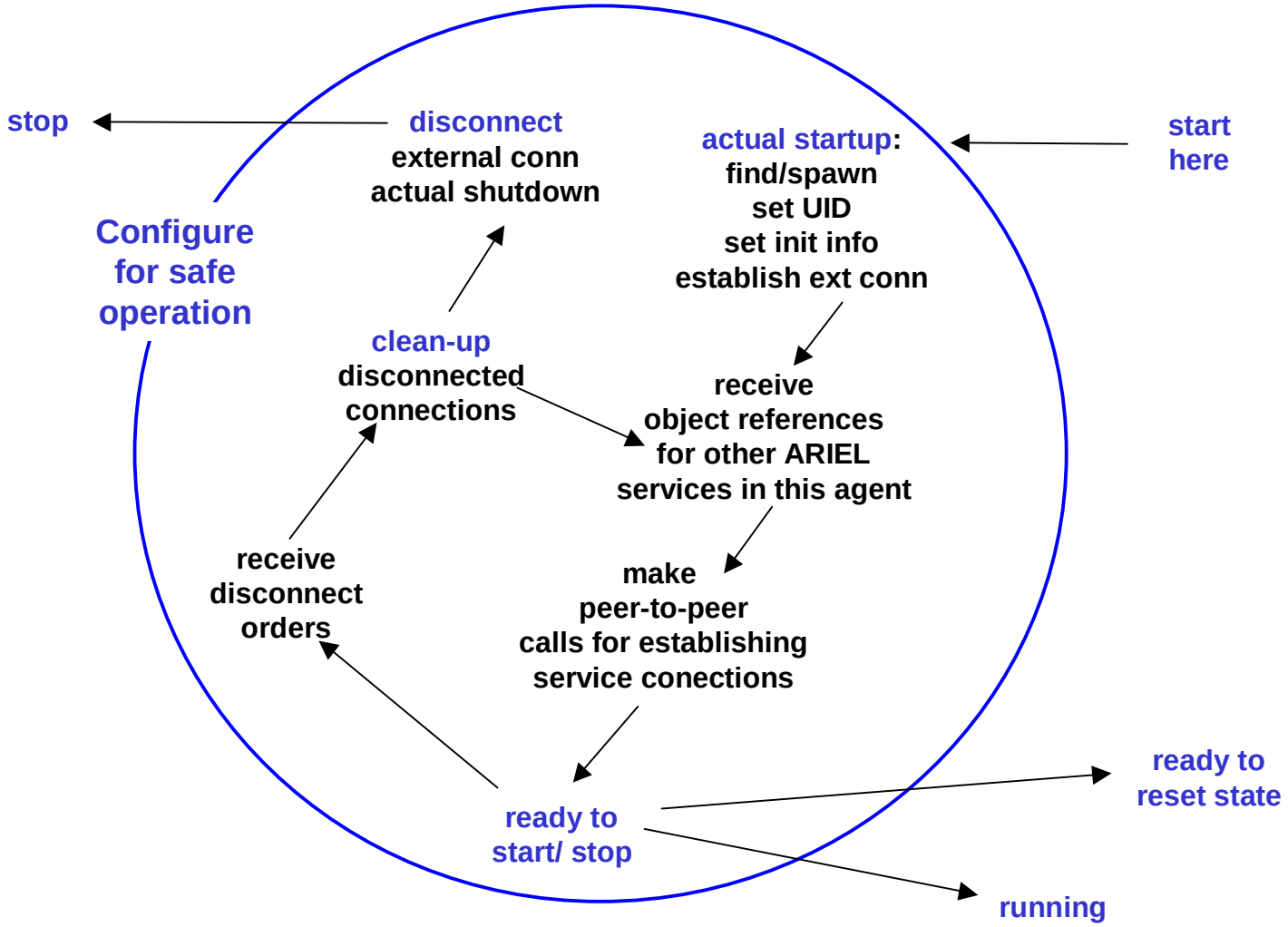
- Interaction between human and his liaison agent
  - **Agent Reconfiguration**: Liaison agent can be configured for different user groups (e.g., crew versus ground controllers)
  - **Notification**: Agent uniformly notifies human using saliency annotations and modality
  - **Plan Management**: Agent updates human schedule in response to fault diagnosis, waiver of flight rule, and procedure tracking
  - *Proposed Research to Intelligent Systems Program*
    - *DCI: Multimodal interfaces for non-intrusive notification (PI: D. Schreckenghost)*



Reconfigurable Liaison Agents

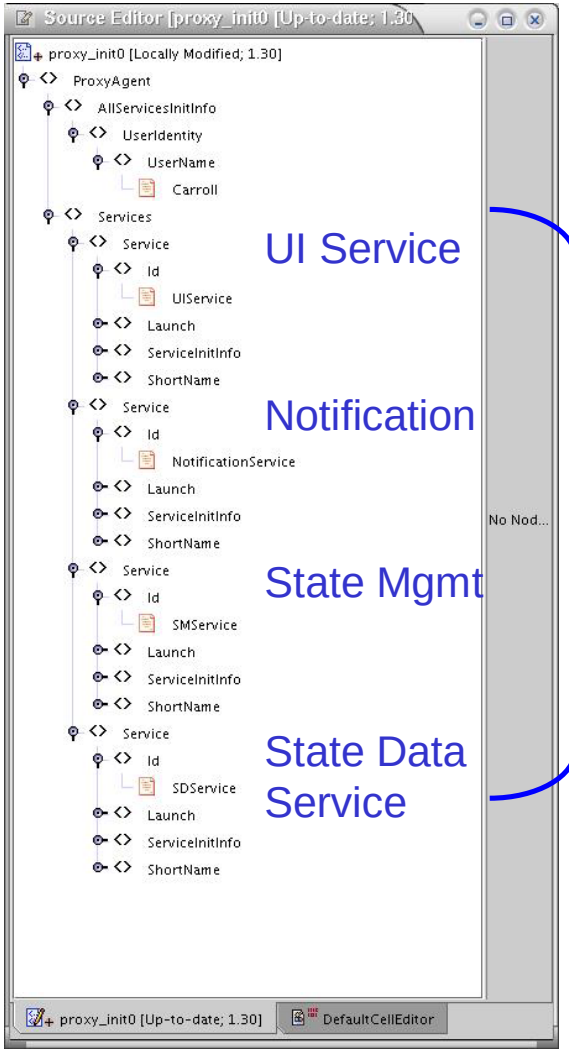
- **Motivation**
  - Use DCI for variety of users requiring different sets of services (e.g., ground controllers vs crew)
  - Use DCI as technology testbed for other researchers
    - Replace existing services with alternative capabilities
    - Add new services
- **New Capabilities**
  - Execute ARIEL agent with a subset of the available services active
  - Shutdown and restart one of many ARIEL services while running
  - Streamline the management of ARIEL agent and services for easier use by us and for reuse by others
- **Key Technologies**
  - Agent beliefs: Centralized blackboard memory management
  - Agent behavior: State model of safe behavior transitions when starting up or shutting down agent
- **Reconfiguration Approach**
  - Change services at startup of agent using xml configuration files
  - Restart executing agent using administrative interface

Reconfiguration State Model

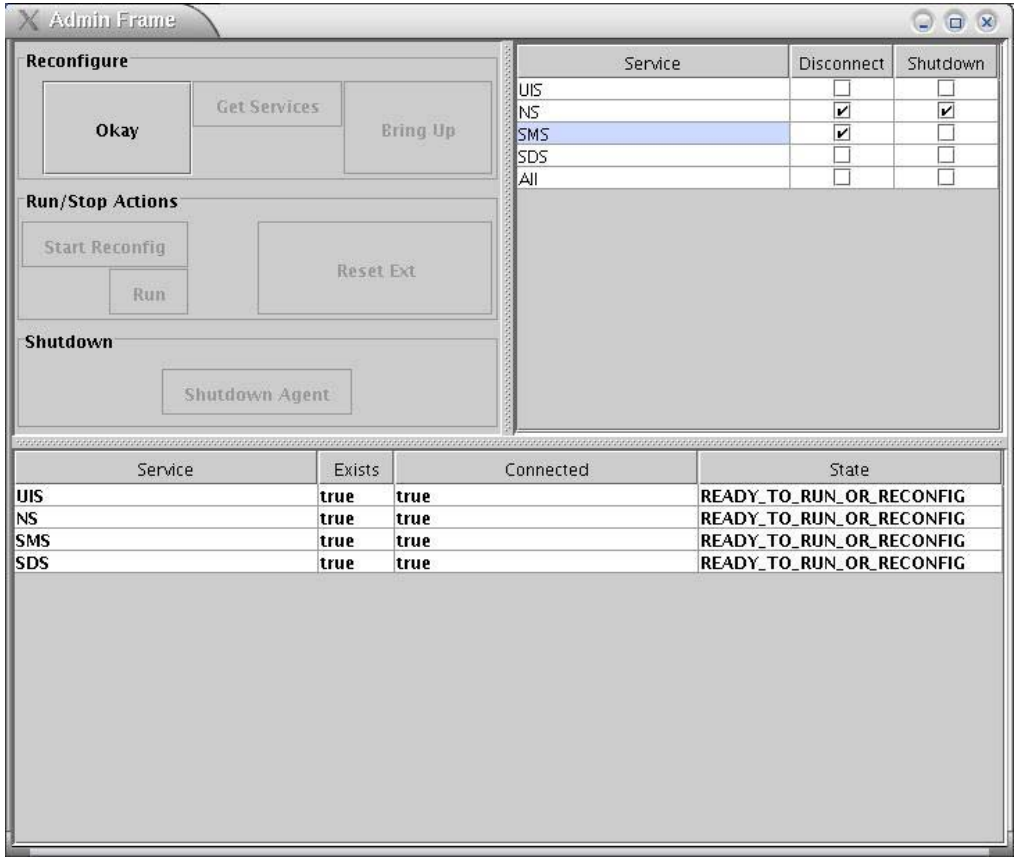


Reconfigure at Agent Startup

Configuration File



Configuration during Execution

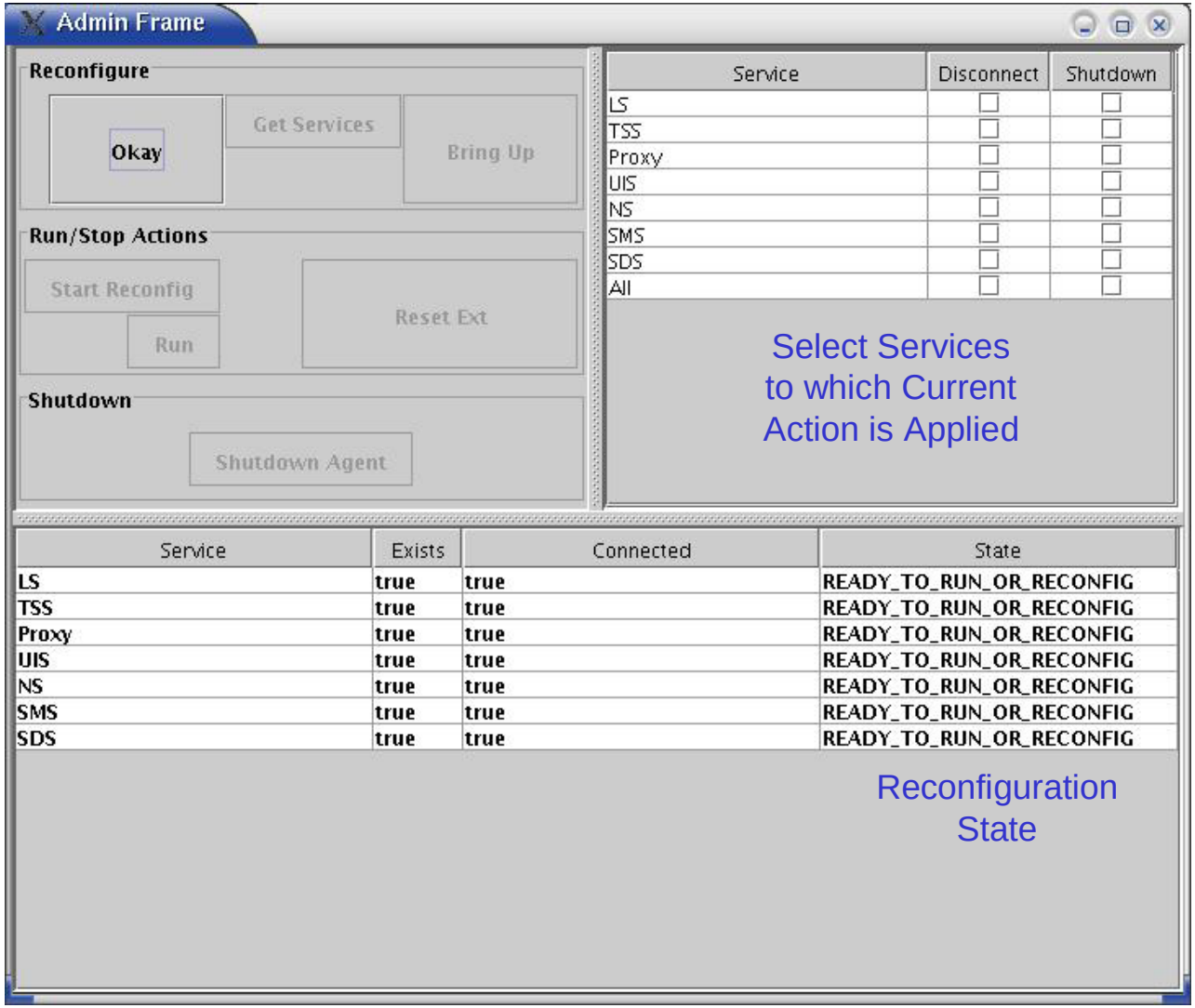


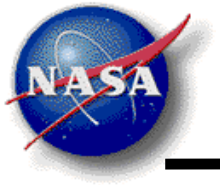
Reconfigure while Agent Executes

Change Services

Mode Switch: run or reconfigure

Shutdown Agent





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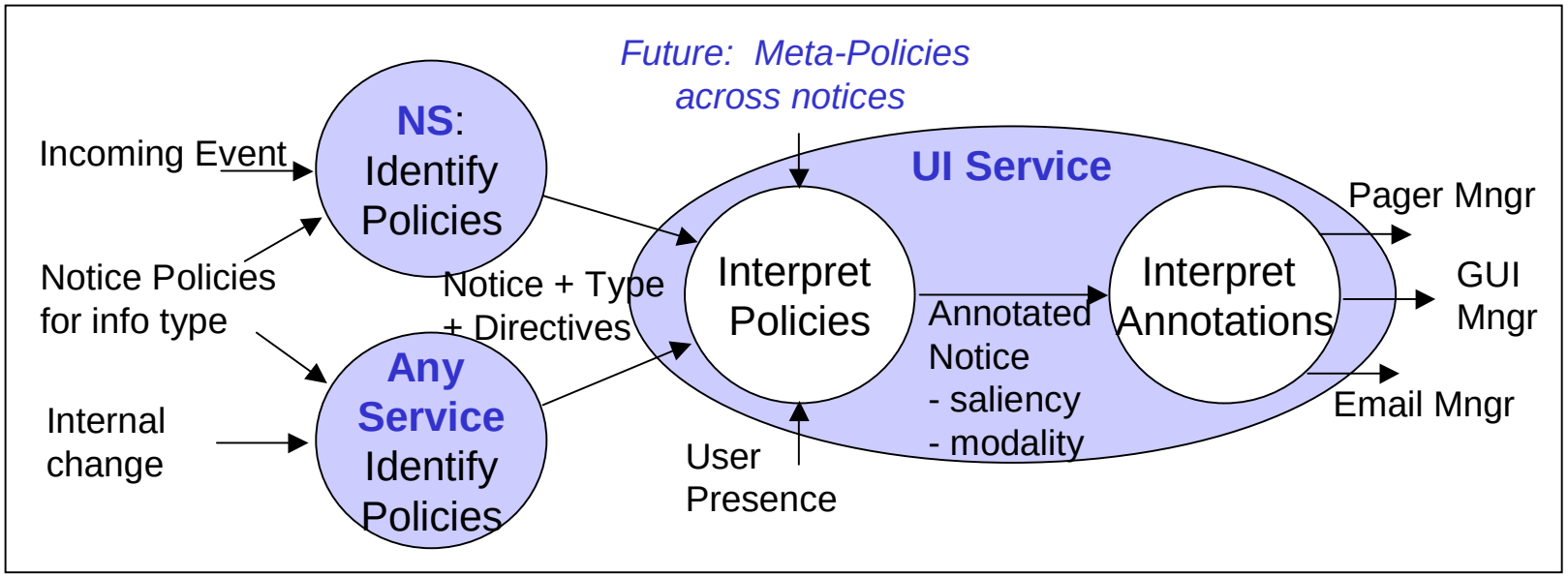
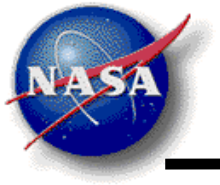
    - *DCI: Multimodal interfaces for non-intrusive notification (PI: D. Schreckenghost)*

Improved ARIEL Service: Notification

- Key Technologies: ontology matching (complex, nested) & filtering of XML notices
- All services annotate notices with latency, focus of attention, and modality; formerly only Notification Service could alert user
- Handling of notice directives moved from Notification Service to UI Service for integrated management
- Benefits
  - Uniform interface for alerting user from any service
  - Escalation of notices by services
  - Integrated presentation of information from different or new services





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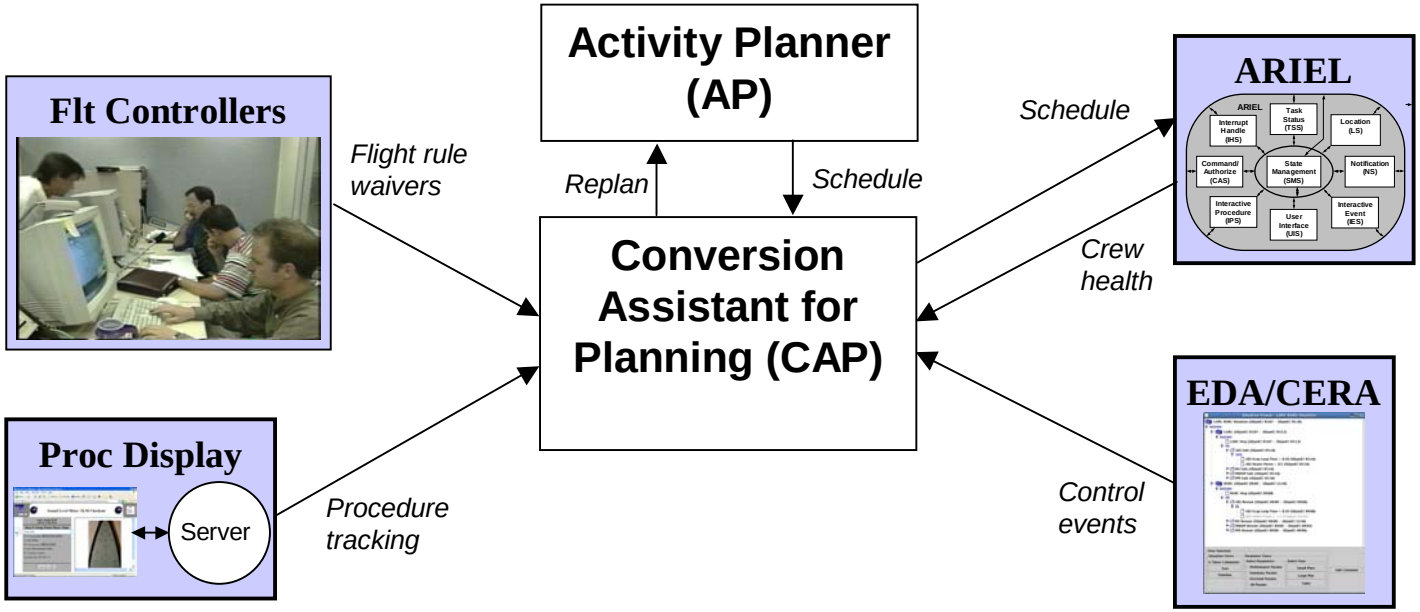
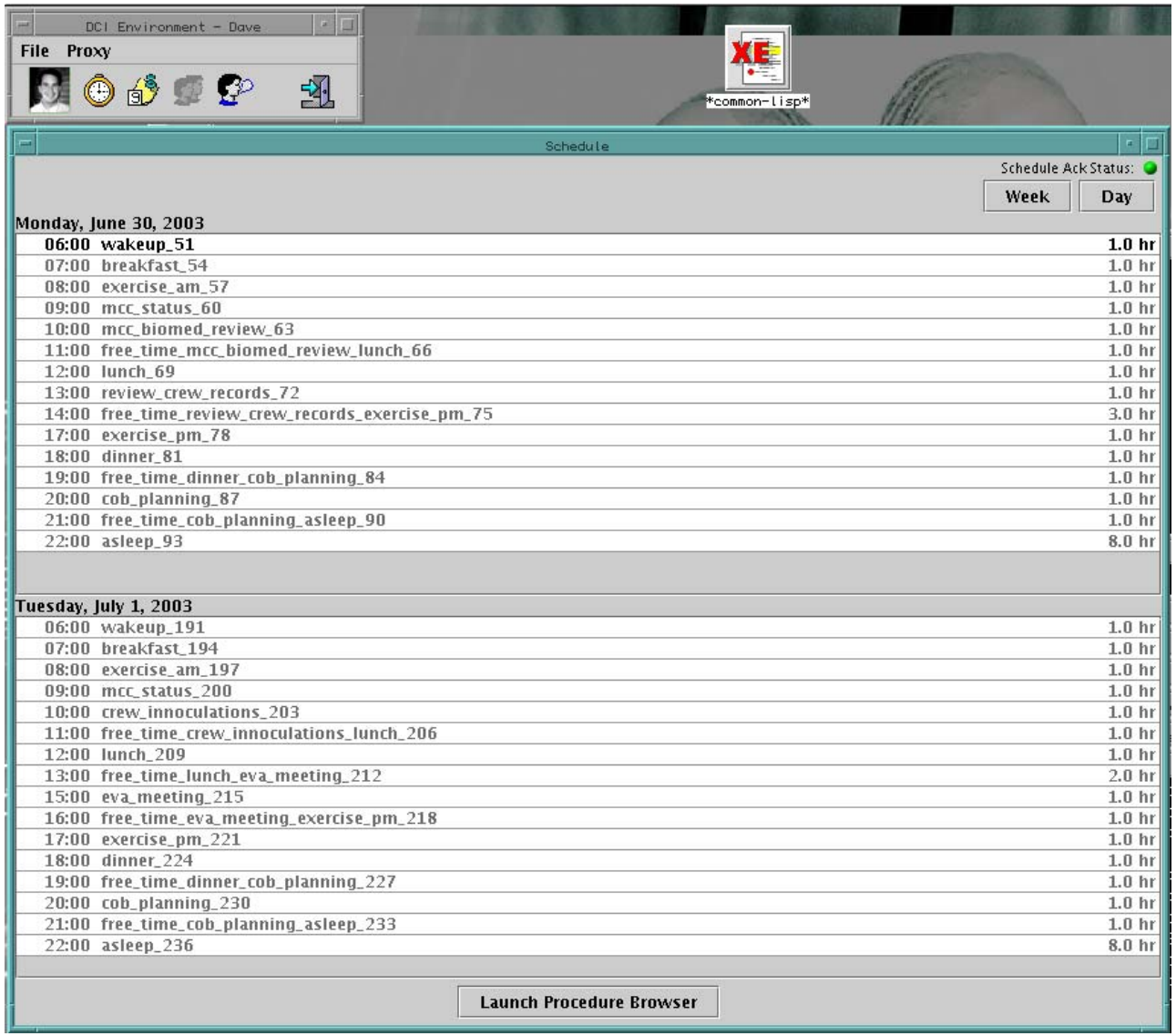
Improved ARIEL Service: Plan Mgmt

- Key Technologies: HTN planner, scheduling algorithms
- Update schedule (replan) in response to
  - Change in health: injured crew
  - Fault diagnosed: equipment failure
  - Waiver of flight rule: mandatory daily crew exercise
  - Procedure tracking: initiated/complete from procedure viewer
- Manage and view multi-day schedule
- Schedule free time when no activity can be scheduled



Multi-day Schedule



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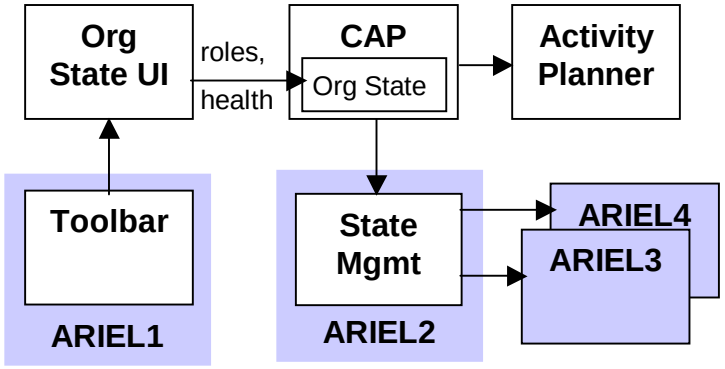
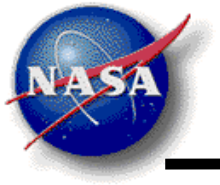
    - *Managing flight rules as organizational policies (Debra Schreckenghost and Jeff Bradshaw/IHMC)*
- Interaction among humans in a group
  - **Agent Communication:** Agent assists interaction among humans
    - Quick Send Messages and Interactive Events: Human notifies the group quickly (e.g., emergency)
    - Key technologies: XML messge content for agent communications, Corba event channels
  - **Awareness of Distributed Group**: Human tracks other team members
    - Service improvements (location, activity) provide better tracking of group members
    - Designs for improved user interface
- Remote interaction with agents
  - **Wireless and Portable Computing**: Human uses handheld to interact with liaison agent or control agent
    - Key Technologies: Java thinlets, HTTP-CORBA servlet, IEEE 802.11 b & g

Organizational Models and Policies

- Organizational State Models used for Plan Management and Group Awareness
  - **Roles** within organization
  - **Crew health** assessment



- Organizational Policies
  - **Notification specifications**: identify information needed to support human roles (filtering, alerting/attention getting)
  - **Policies for command authorization**: define scope of command authorization based on expected effects on system/subsytem
  - **Flight rules**: constraints affecting crew health and safety, vehicle integrity, and mission capability (e.g., waive exercise changes crew schedule)



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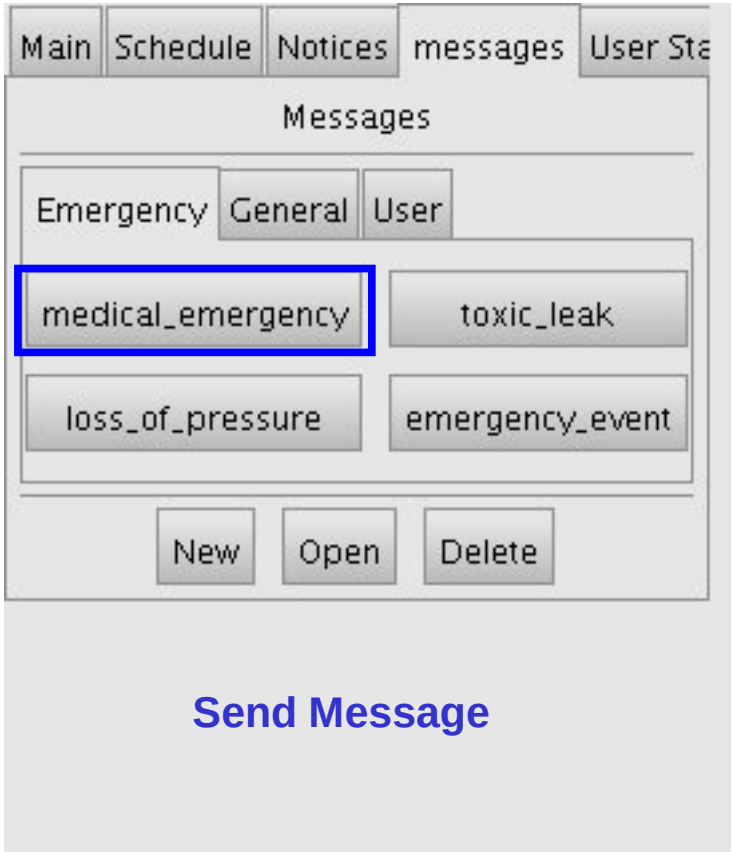
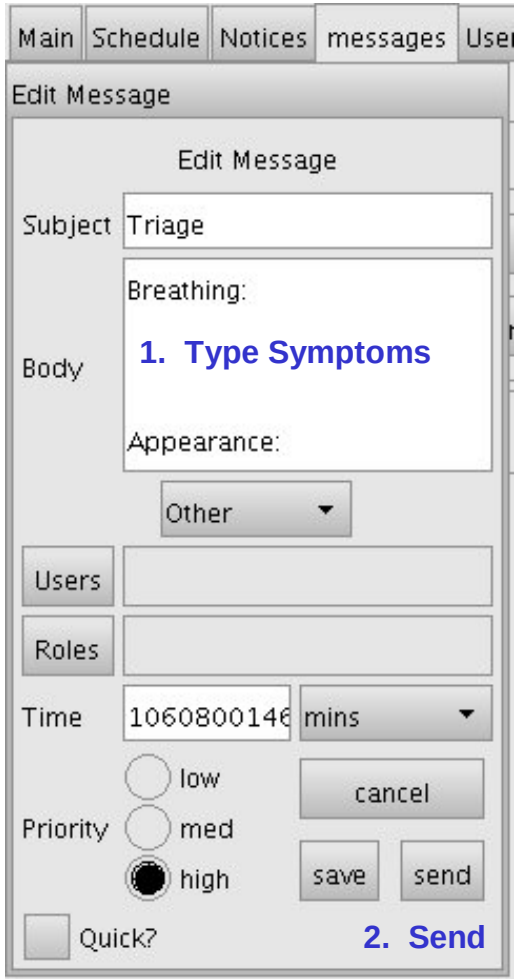
Agent Communication

Quick Send Messages

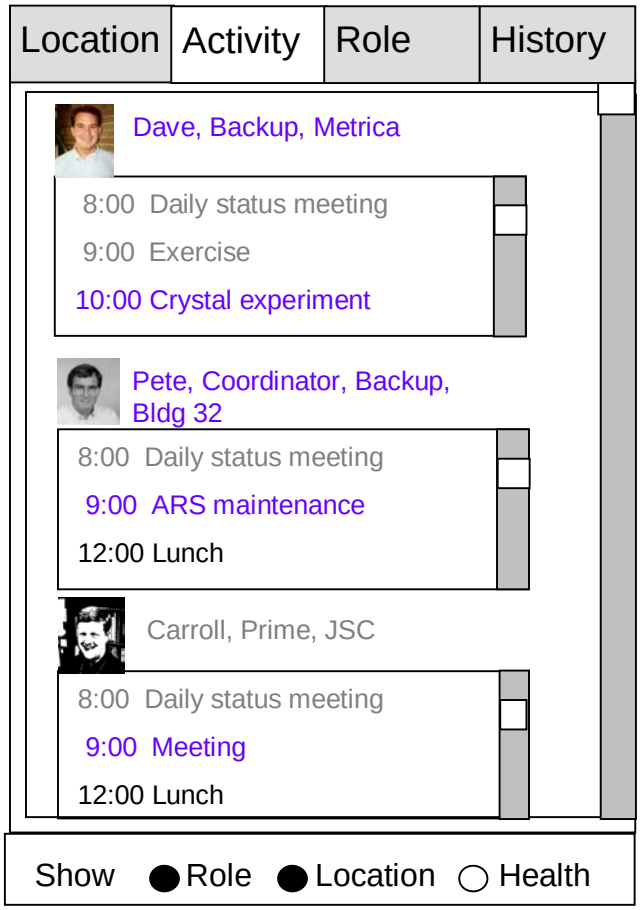


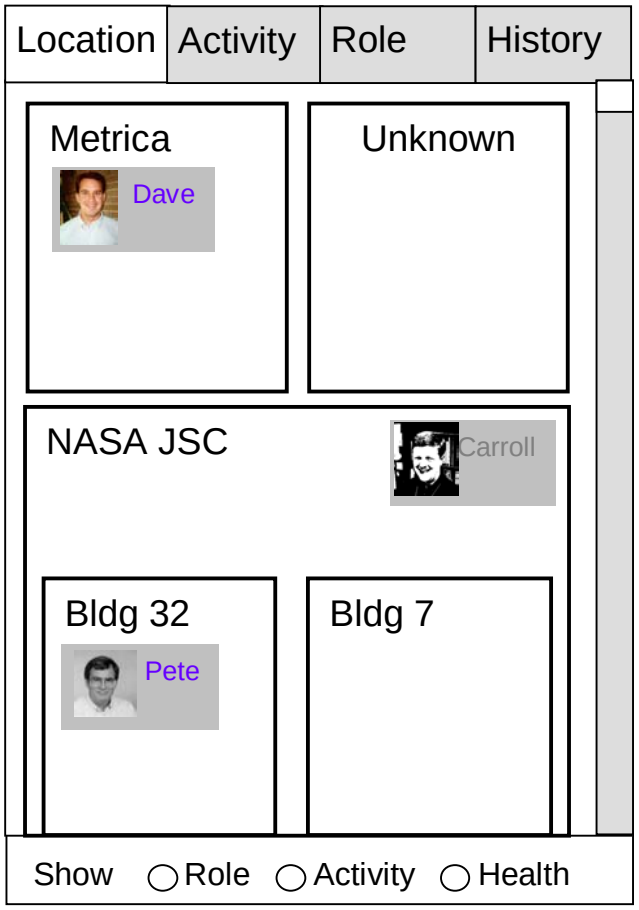
Send Message

Interactive Events



Design: Awareness of Distributed Group





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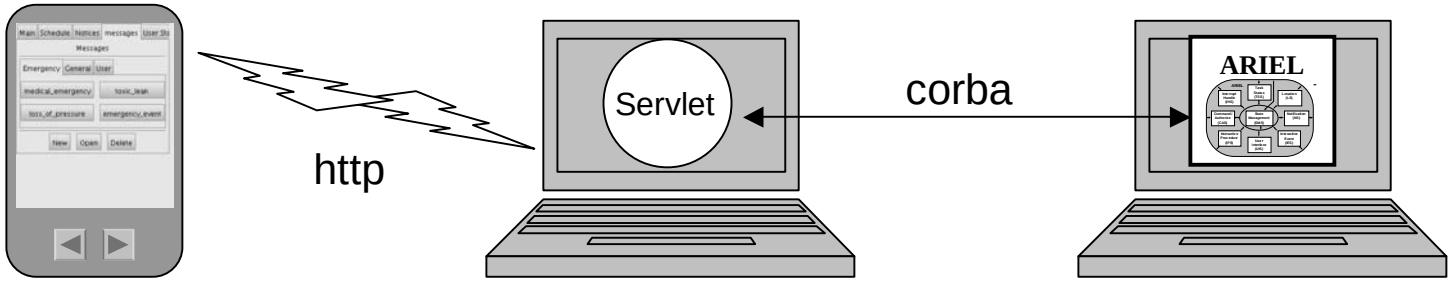
Wireless and Portable Computing

- DCI GUI on Sharp Zaurus handheld running Linux
  - Thinlets for Java displays under j2me
    - XML specification maps to Java AWT classes
    - Quick development but subset of Swing capability
  - Communication using servlet that maps http to corba
    - CORBA compiled on handheld but was memory constrained
    - HTTP was only reliable communication protocol on handhelds



- Utilization of both IEEE 802.11b and 802.11g protocols
  - LinkSys access points for both protocols running in Metrica lab
  - Good backwards compatibility using 802.11g cards with 802.11b access points

Proposed Work for FY04-05

- **Multimodal interfaces for non-intrusive notification**
  - Model intrusiveness: consider User Interruptibility, Notice Significance, and User Tolerance for Interruption; coordinate with Dr. Jiajie Zhang
  - Evaluate multimodal interfaces with Dr. Nadine Sarter/OSU
    - Strategies for information presentation that encode notices on multiple perceptual channels as well as increase saliency within a channel.
    - Effectiveness of the model of intrusiveness in determining whether to interrupt or queue notices
- **Automated sequence execution and tracking of procedures**
  - Adjusting autonomy to support interleaved manual and automated tasks
  - Activation of automated task sequences (procedure fragments); e.g., consensual automation
  - Tracking completion of procedure steps
  - Interaction capabilities needed to effectively use this capability
- **Evaluation in the Advanced Water Lab at JSC**
  - Test of Post-Processing System (PPS) hardware begins this fall and will last 1.25 years (Sep/03 – Dec/04)
  - Deploy and evaluate ARIEL agents in use during this test
    - Initially support notification and task re-assignment at anomalies
    - Later phases include situation capture and remote commanding

Workshops and Demonstrations

Video (DVD)

DCI Support for Advanced Water Lab: Loss of Communication in Advanced Water Lab. Includes copies of recent publications. Artistic Direction: R. Peter Bonasso.

Demonstrations

Schreckenghost, D., P. Bonasso, D. Kortenkamp, C. Martin, T. Milam, C. Thronesbery. Demonstration: Liaison Agents for Distributed Space Operations. *IJCAI Intelligent System Demonstration*. Acapulco, Mexico. August 2003.

Organized Related Workshops

M. Freed, D. Kortenkamp, and D. Schreckenghost.

Workshop on Human Interaction with Autonomous Systems in Complex Environments.
AAAI Spring Symposium 2003.
Stanford University, CA. March 2003.

C. Martin and D. Schreckenghost.

Workshop on Humans and Multi-Agent Systems
2nd International Conference on Autonomous Agents and Multi-Agent Systems
Melbourne, Australia, 2003. July 14, 2003.

Publications

Journals and Magazines

Schreckenghost, D., C. Thronesbery, P. Bonasso, D. Kortenkamp, and C. Martin. "Applying Human-Centered Computing to Intelligent Control of Life Support for Space Missions". *IEEE Intelligent Systems*, special issue on Human-Centered Computing at NASA. Sept/Oct 2002.

Schreckenghost, D., C. Martin, P. Bonasso, D. Kortenkamp, T. Milam, & C. Thronesbery. Supporting group interaction among humans and autonomous agents. *Connection Science*. Vol 14, No 4. 2002. pp 361-369.

Conferences

Schreckenghost, D., C. Martin, and C. Thronesbery. Specifying Organizational Policies and Individual Preferences for Human-Software Interaction. AAAI Fall Symposium. *Workshop on Etiquette for Human-Computer Work*. Nov 2002

Martin, C., D. Schreckenghost, P. Bonasso, D. Kortenkamp, T. Milam, and C. Thronesbery. Aiding Collaboration among Humans and Complex Software Agents. AAAI Spring Symposium. *Workshop on Human Interaction with Autonomous Systems in Complex Environments*. March 2003.

Martin, C. E., D. Schreckenghost, R. P. Bonasso, D. Kortenkamp, T. Milam, and C. Thronesbery, "Helping Humans: Agents for Distributed Space Operations," presented at The *7th International Symposium on Artificial Intelligence, Robotics and Automation in Space*, Nara, Japan, 2003. May 19-23.

Martin, C. E., D. Schreckenghost, R. P. Bonasso, D. Kortenkamp, T. Milam, and C. Thronesbery, "An Environment for Distributed Collaboration Among Humans and Software Agents," presented at *Workshop on Humans and Multi-Agent Systems* at the *2nd International Conference on Autonomous Agents and Multi-Agent Systems*, Melbourne, Australia, 2003. July 14-18..

Thronesbery, C., and Schreckenghost, D., Situation Views: Getting Started Handling Anomalies. *IEEE International Conference on Systems, Man, and Cybernetics*. Washington, D. C. Oct 5-8, 2003

Schreckenghost, D., Panel on the Etiquette Perspective for Human-Automation Relationships: Applications, Models, and Results. Organized by Dr. Chris Miller/SIFT. *Human Factors and Ergonomics Society (HFES*). Denver, CO. Oct 2003.

Video: DCI Support for Water Lab

- Captures human-agent interaction for use in collaborating with other researchers
- Illustrates the distributed operations problem at NASA that DCI tries to solve
- Supplements poster sessions and demonstrations
  - ISAIRAS 2003
  - AAMAS 2003
  - IJCAI 2003
- Packages the DCI research in an easily distributable form
  - Video
  - Research papers
  - Contact information